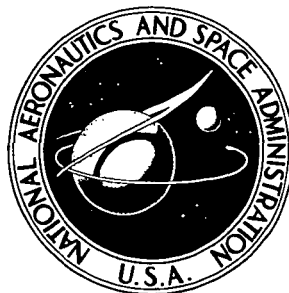


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**DESCRIPTION AND EXPECTED PERFORMANCE
OF FLIGHT-MODEL, 12-GIGAHERTZ, OUTPUT
STAGE TUBE FOR THE COMMUNICATIONS
TECHNOLOGY SATELLITE**

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SUMMARY

This report describes the flight model output stage tube for the Communications Technology Satellite. The tube was manufactured by Litton Industries, Electron Tube Division, San Carlos, California. It is designated model L-5394; the flight tube serial number is 2022 R-1. The output stage tube is a 12-gigahertz, 200-watt, coupled cavity traveling wave tube. The tube has a multistage depressed collector for efficiency enhancement. Collector cooling is accomplished by direct radiation to space. Expected radiofrequency performance and factors affecting on orbit performance and life are discussed.

INTRODUCTION

The Communications Technology Satellite (CTS), jointly developed by NASA and the Canadian Department of Communications, was launched into a geostationary orbit early in 1976. The launch vehicle, a three-stage Delta model 2914, placed the satellite in a stationary equatorial orbit at 116° west longitude at an altitude of about 22 000 miles. From this position just west of South America, CTS is broadcasting, in a newly allocated satellite frequency band (12 GHz), to Canada and all 50 United States. With the use of new technology, the CTS transmitting power level is up to 20 times greater than that of currently operating satellites and permits television reception and two-way voice communication with relatively inexpensive ground equipment in the areas served. The satellite will be used, in addition to demonstrating new technology, to conduct a number of communication experiments concerned with satisfying national needs by users representing many segments of society. The communication experiments include innovations re-

lated to education, medicine, business, emergency services, and radio and television propagation.

One of the major technological objectives of the joint United States - Canadian, program for the Communications Technology Satellite is the development of a power tube having greater than 50 percent efficiency at a minimum output power of 200 watts and operating at approximately 12 gigahertz. The power tube developed to meet this objective has been designated the output stage tube (OST). This tube is a part of the transmitter experiment package (TEP), which consists of an output stage tube, the power processing system (PPS), and a variable conductance heat pipe system (VCHPS) to carry heat to a fin for radiation cooling. Previous reports on high power tubes for the communications technology satellite mission (see refs. 1 to 5), have dealt mainly with the generic design and development of the output stage tube. This report describes the actual hardware selected for launch and lists its expected performance.

DESCRIPTION OF THE OUTPUT STAGE TUBE (OST)

The output stage tube (OST) for the Communications Technology Satellite mission is a 12-gigahertz, 200-watt, coupled cavity traveling wave tube. Figure 1 shows OST serial number 2030, which is representative of the flight hardware configuration. The tube was manufactured by Litton Industries of San Carlos, California. It is designated model L-5394; the flight tube serial number is 2022 R-1. The R-1 signifies that this tube was rebuilt one time. The rebuilding was required to replace the collector with one that could pass the required vibration tests. Because the operation required admitting air to the previously evacuated and processed tube, the electron gun was replaced as a matter of course.

The OST has four basic elements: the electron gun, the radiofrequency (rf) section, the refocusing section, and the collector. These elements are shown schematically in figure 2. Electrons pass from the electron gun, through the rf and refocusing sections to the collector and are returned to the cathode through an external power supply to complete the electrical circuit. The following sections describe each of these elements in turn.

Electron Gun

The electron gun consists of a heater, a cathode, and an anode. Electrons are emitted from the hot cathode and are drawn towards the anode by an electric field produced by an external power supply. The electrons pass through a hole in the anode and

are focused magnetically to provide a compact, laminar electron beam which is used in the amplification process.

The cathode in the flight tube is an oxide impregnated tungsten matrix cathode that operates at a current density of 0.559 amperes per square centimeter at a true operating temperature of 1125° C. Cathode knee temperature during final testing was 1020° C true. Cathode diameter is 0.416 centimeter. The measured converged beam minimum (95 percent) for the flight electron gun was 0.0725 centimeter in diameter and occurred 0.94 centimeter beyond the anode face. Heater current for the flight gun was 1.29 amperes.

Radiofrequency Section

In general, traveling wave tubes that provide more than 20 decibels of gain consist of several sections joined by terminations or severs. The severs prevent feedback between sections and the rf input and output, thereby suppressing oscillations. The rf section or slow wave structure is composed of an input section, first sever (or termination), center section, second sever, and output section. The configuration of the various sections is shown in table I.

The output section is composed of a series of cavity sets which are arranged in the order shown in table I and designated STD 1, STD 2, and T-1 to T-8.

The cavity walls are machined from copper clad vacuum quality iron to a tolerance of 0.0127 millimeter (0.0005 in.). Cavity spacers are machined from oxygen free, high-conductivity (OFHC) copper to the same tolerance. Cavities are first brazed together to form the individual sections. These sections are then brazed together with input and output wave guides and severs to form the tube circuit or slow wave structure.

In traveling wave tubes the average velocity of the electron beam is less than the speed of light, yet the rf wave that is to be amplified is propagating down the input wave guide at approximately the speed of light. Therefore, to achieve synchronism of the rf wave and the beam, so that they may interact, the rf wave must be slowed by the characteristics of the circuit. This is accomplished in coupled cavity tubes by periodic loading of the circuit by means of coupling slots between the cavities and the gap capacity. The rf structure then acts somewhat like a lumped element delay line to slow the rf wave.

The traveling wave interaction takes place in the following manner. First, an rf wave is impressed on an electron beam. This rf-wave velocity modulates the beam by speeding up some of the electrons and retarding others. In addition, the rf wave is also coupled through the rf or slow wave structure so that the currents the wave induces in the slow wave structure are in phase with the currents induced in the structure by the bunched electron beam. These currents on the surface of the cavities give rise to an

electric field or circuit wave that travels through the structure from the gun end of the circuit to the collector end. Practical traveling wave tubes also arrange the velocity of the electron bunches such that they experience a retarding effect by the circuit wave at almost all the tunnel gaps in the coupled cavity structure. They can therefore effect a net energy transfer from the beam to the circuit wave. This continual interaction produces a growing electromagnetic wave on the circuit such that the energy can be extracted through a small coupling slot into the output wave guide.

It should be pointed out that the interaction cannot continue indefinitely because, as the kinetic energy of the beam is converted to rf energy, the average velocity of the beam decreases. Ultimately, the beam and circuit wave will fall out of synchronism, and debunching will occur with a resulting efficiency loss. This is a basic limitation on the conversion efficiency of direct current to rf energy in a traveling wave tube. The OST also makes use of an additional technique to maintain the condition of synchronism and obtain a higher conversion efficiency. This technique is to change the velocity of the circuit wave with respect to the beam. This is done by physically changing the spacing between the cavity walls near the output of the circuit. Thus, the circuit wave seems to gain ground on the beam bunches and prolong the synchronous condition, which is favorable for energy transfer from the beam to the circuit.

Focusing

The electron beam is focused or controlled in the rf section by means of permanent magnets. The magnets are made of samarium cobalt. The peak axial field is 1500 gauss in the input, center, and standard output sections and 2200 gauss in the output taper section.

After passing through the rf interaction region and before entering the collector, the beam passes through the refocusing region. A permanent magnet is used here to control the electron beam and establish the desired conditions for entry into the collector. The refocusing magnet for the flight tube is a single ring, samarium cobalt magnet. Its field strength is 510 gauss.

Collector

The collector is what its name implies - a collector for the electrons in the beam. The function of the multistage depressed collector (MDC) as shown in figure 2(a) is to transform the residual kinetic energy of the beam into potential energy, thereby increasing the overall efficiency of the tube-collector combination and reducing the heat load on the collector. A complete discussion on the multistage depressed collector can be found

in references 4 and 5.

The collector consists of 10 spun molybdenum electrodes, an electrically insulated support structure and a vacuum enclosure. The cone angle of the electrode apertures is 4° with respect to a line parallel to the tube axis. The collector is cooled by direct radiation to space. A thermal choke is installed between the electrode support structure and the tube body to minimize soakback to the spacecraft. Radiation shields are also installed within the collector between the tube body and the first collector electrode to minimize radiation soakback.

The MDC used has a unique feature in that shadow shields are incorporated on all collector insulators to prevent metallic deposition, caused by ion impingement on the spike, from shorting electrodes together during processing or operation. The shields were added after the failure of an early test device. Although the failure of the early device was later attributed to the high gas pressure of an insufficiently processed tube, the shadow shields were installed in all subsequent tubes as a precautionary measure.

Packaging

The output stage tube is packaged for flight in the following manner. First, saddles (U-shaped blocks) are attached to the traveling wave tube body at its input and output. (See fig. 2(b).) These in turn are bolted to the OST heat sink (baseplate). This provides a path for heat generated in the circuit from skin effect losses and beam interception to be removed from the structure. Indium foil is used to improve thermal conductivity in the joints between the body and saddles and between the saddles and heat sink. A cantilevered truss structure forms the sides and top of the OST package and transmits the overhanging collector load into the OST mounting surface (fig. 1). Input and output waveguides are supported by an additional truss structure. The two ion pumps are supported by brackets which are bolted to the main truss structure.

Notch Filter and Output Coupler

As the basic rf circuit design evolved, it became apparent that there was a large gain peak below the CTS band (see fig. 3). To meet the requirements imposed on the OST by the CTS spacecraft transponder, it was necessary to modify the OST response by means of a reflective notch filter at the input of the OST. This device reflects almost all of any signal below the CTS band and therefore permits the OST to operate properly with the transponder. A plot of the notch filter insertion loss and return loss for OST 2022 R-1 is shown in figure 4.

Early in the program it was also desired to have a direct measurement of the OST output power and the reflected power returned to the OST due to mismatch. The measurement was effected by means of the output coupler. This device is two back-to-back directional couplers brazed together. One coupler measures the power transmitted to the load and the other measures the power reflected from the load. An rf detector diode is immersed in the electric field of each coupler and provides a signal proportional to the desired parameter. These signals are amplified in the signal conditioning circuitry of the power processing system and relayed to the ground via spacecraft telemetry.

Processing

The flight OST was baked out in a double vacuum retort before the hot test. The inside of the OST was evacuated at high temperature to remove gas and volatile compounds and provide the vacuum necessary for successful cathode operation and life. The vacuum outside of the tube (at the same time as the internal vacuum) prevented atmospheric oxygen from attacking the circuit braze material and causing leaks. It also prevented the exterior of the copper circuit from oxidizing.

Several salient features of the exhaust procedure were as follows:

- (1) The tube body was baked at 450°C , collector at 600°C .
 - (2) The cathode was hot flashed for 10 minutes at 1200°C when the tube internal pressure reached 0.1067 millipascal ($\leq 8 \times 10^{-7}$ torr).
 - (3) The cathode operated at 1100°C during remainder of exhaust processing run.
 - (4) The tube was processed for 13 hours after low pressure asymptote was achieved.
- After the exhaust procedure, preliminary packaging was done. This included bonding of the bus bars and attachment of the gun leads and shield. The magnets were installed, then the tube was focused. Bus bars for the longitudinal transfer of heat were bonded to the tube body with Eccobond 56 C epoxy and catalyst 9. Magnets were bonded to the tube with Stycast 2850 FT and catalyst 9. The flight tube also had Eccobond 56 C silver loaded epoxy between all magnets and the bus bars to improve magnet cooling. The tube was initially operated at 0.1 percent duty cycle and then the operating duty cycle was raised to continuous operation (cw) at all drive levels with the collector can externally heated to 300°C . This allowed removal of gases released by impingement of the electron beam on various collector plates.

After NASA had determined that OST 2022 R-1 was a candidate for a flight tube, final packaging was carried out. This included the addition of structural support members, thermistors, collector painting, and air bakeout to outgas the exterior of the tube. The collector was painted with Spherex SP-101, VHT, high temperature white paint. The OST exterior bakeout was for 12 hours at 125°C in air.

OST QUALIFICATION PROGRAM

The OST has been qualified for flight by a combination of component and spacecraft level tests.

Vibration

The OST component vibration qualification test consisted of qualification by similarity to OST 2023, which was representative of the flight models except for the following deviations:

- (1) The collector jacket has a circumferential weld.
- (2) Some high voltage leads inside the collector were spliced and welded when an insulator was replaced.
- (3) The bellows was punctured and welded shut.
- (4) A sever cavity was crimped to secure a loose sever.
- (5) The tube had an rf short in the output section; therefore, operation was only permitted at 10 watts output power.

The OST 2023 was sine and random vibration tested in three axes to the qualification levels cited in table II. After the first axis Y qualification sine test, it became apparent that the ion pump support brackets were inadequate. The design was changed and new brackets were installed. The remaining qualification vibration tests were completed, and no degradation of the OST was noted. The redesigned ion pump brackets were incorporated into OST 2022 R-1 and all subsequent OSTs.

The flight OST serial number 2022 R-1 was also sine and random vibration tested to the flight acceptance levels (qualification levels of table II divided by 1.5). No degradation due to vibration testing was noted.

Thermal Vacuum

While OST 2022-R1, the flight unit, was subjected to acceptance-level thermal-vacuum testing (table III) at Lewis, it was later returned to Litton for focus trimming at elevated temperature. It was not returned to Lewis after that, but was integrated with the flight power processor and was subjected to limited acceptance-level thermal-vacuum testing at TRW, Inc., the TEP prime contractor. Consequently, current experimentally-determined thermal characteristics for this OST are not available. However, information derived from the electrical results (only) obtained in the TRW testing gave rise to the estimates of the current OST 2022-R1 thermal characteristics presented in table IV. From the earlier Lewis tests the maximum collector cover temperature was

found to be 227⁰ C with the OST operating in the direct current beam (zero rf output power) condition and the baseplate temperature at 45⁰ C. This temperature level should not have been significantly affected by the focus trim procedure. Correcting this temperature to account for solar input would adjust it to be about 232⁰ C at the beginning of operation.

The OST component thermal-vacuum testing consisted of qualification by similarity with the flight backup unit OST 2025, which is identical in configuration to the flight unit. Like OST 2022-R1, OST 2025 was trim-focused at elevated temperature at Litton after thermal-vacuum testing at Lewis. Following the trim-focusing procedure, OST 2025 was returned to Lewis, where it was flight-qualified by subjecting it to the qualification thermal-vacuum testing levels.

System Tests

The following components were integrated into the protoflight spacecraft for TEP Systems tests: PPS QF-02, OST 2022 R-1, and VCHPS FM-005. Before spacecraft installation, the PPS and OST had each received a flight acceptance vibration test and thermal vacuum test as individual components. Then the PPS and OST were integrated as a TEP and subjected to a flight acceptance thermal vacuum test. The VCHPS received a flight acceptance vibration and thermal vacuum test as an individual component.

Spacecraft vibration testing. - The protoflight spacecraft with flight OST installed was subjected to a three-axis sinusoidal vibration test at levels 1.2 times the expected flight levels and a three-axis random vibration test at levels 1.5 times the expected flight levels. The spacecraft was then subjected to a shock test which was conducted by firing the pyrotechnic devices. No degradation of the OST was observed during these tests.

Spacecraft thermal-vacuum testing. - The protoflight spacecraft with flight OST installed was subjected to thermal-vacuum testing including four periods of elevated temperature, three periods of cold temperature, and eight transitional periods. The OST was operated at all low temperature periods, all, except one, high temperature periods, and all transitional periods. No degradation of the OST was observed.

Based on the combination of the component qualification effort and systems qualification performed on the protoflight spacecraft described in the document, it was concluded that the OST was qualified for flight on the CTS spacecraft.

FACTORS AFFECTING ON ORBIT PERFORMANCE

Cathode Life

It is probable that the ultimate operating life of OST 2022 R-1 will be determined by the life of the thermionic cathode. Figure 5 shows life test data obtained on impregnated cathodes. These cathodes contain barium oxide, calcium oxide, and aluminum oxide in the molar ratio 5:3:2. This is the same ratio that Litton used to fabricate the cathodes for the CTS tubes. Noting that OST 2022 R-1 operates with a true cathode operating temperature of 1125°C , it is predicted that the cathode life is 17 300 hours. Approximately 1800 hours of this life have already been utilized in ground testing.

Collector Cover Thermal Control Coating

The thermal control coating for the OST collector enclosure ideally should have a relatively high thermal emittance, a relatively low solar absorptance, and longterm property stability. The coating selected (Sperex SP 101, VHT, white paint) had a thermal emittance of about 0.9 in limited tests at Lewis; its other properties and stability were not evaluated. Some thermal control coatings (ref. 6) experienced, in space environment testing, an increase in solar absorptance, presumably due to ultraviolet radiation. In some cases cited in the reference, the increase in solar absorptance was significant and rapid. Conservatively assuming that such a change may take place with the coating used on the OST collector enclosure, an increasing collector cover surface temperature for a constant heat rejection rate may be anticipated. This would result in changes in the heat exchange across the thermal choke which separates the OST coupled-cavity region from the collector. Since OST body current is influenced directly as body temperature, the operation of the OST could be adversely affected by an increase in temperature of the coupled-cavity portion of the tube. Any change in the solar absorptance is expected to be small, however, and result in the collector cover maximum temperature increasing about 5°C , from about 232°C at the beginning of operation to about 237°C after 2 years.

EXPECTED RF PERFORMANCE

OST rf performance is a function of OST temperature. In turn, the OST temperature is a function of the spacecraft environment. Therefore, those data that most closely simulate the flight environment, namely, spacecraft level thermal vacuum test conditions, can be used to predict the flight OST performance. When the OST is operated in

space the expected rf performance is as follows:

Figure 6 shows the OST rf response during spacecraft testing in vacuum with a body temperature of 50° C. The input power was held constant for each of the power against frequency curves. The output power is greater than 200 watts across most of the CTS band (12.038 to 12.123 GHz) for the saturated condition. Figure 7 shows the OST power transfer curve at 12.080 gigahertz. The curve has a gain variation of less than 0.7 decibels from low level to the saturation -3 decibel level. The OST efficiency under vacuum conditions was 40 percent or greater, except at the upper edge of the CTS band. Figure 8 shows the efficiency of the OST at the expected operating temperature of 45° C.

CONCLUDING REMARKS

The joint United States - Canadian Memorandum of Understanding for the Communications Technology Satellite project lists as one of the major technological objectives, the development of a power tube having greater than 50 percent efficiency, at a minimum output power of 200 watts and operating at approximately 12 gigahertz. It can be seen from the preceding that the OST developed for the CTS mission meets the majority of this objective. It is also felt that the OST developed by the combined efforts of Lewis Research Center and Litton Industries provides a major step in advancing the technology of high-power microwave tubes for communications use in space.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, June
610-22.

REFERENCES

1. Alexovich, R.: The 200 Watt SHF Transmitter Experiment Package. 1972 National Telecommunications Conference, Inst. of Electrical and Electronics Engrs., Inc., 1972, pp. 35C-1 to 35C-4.
2. Franklin, C. A.; and Davison, E. H.: A High-Powered Communication Technology Satellite for the 12 and 14 GHz Bands. AIAA Paper 72-580, April 1972.
3. Kosmahl, Henry G.; McNary, B. D.; and Sauseng, Otto: High Efficiency, 200 Watt, 12-Gigahertz Traveling Wave Tube. NASA TN D-7709, 1974.
4. Kosmahl, Henry G.: A Novel, Axisymmetric, Electrostatic Collector for Linear Beam Microwave Tubes. NASA TN D-6093, 1971.

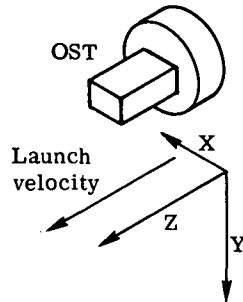
5. Kavanagh, Francis E.; Alexovich, Robert E.; and Chomos, Gerald J.: Evaluation of Novel Depressed Collector for Linear Beam Microwave Tubes. NASA TM X-2322, 1971.
6. Plunkett, Jerry D.: NASA Contributions to the Technology of Inorganic Coatings. NASA SP-5014, 1964.

TABLE I. - OST CIRCUIT CONFIGURATION

Section	Number of cavities	Period		Cavity diameter		Cavity height		Gap	
		cm	in.	cm	in.	cm	in.	cm	in.
Input	10	0.3175	0.1250	1.5113	0.595	0.2413	0.095	0.097	0.0382
Center	14	0.3175	0.1250	1.5113	0.595	0.2413	0.095	0.097	0.0382
Output									
STD 1	10	0.3175	0.1250	1.5113	0.595	0.2413	0.0950	(a)	(a)
STD 2	3	.3040	.1197	1.544	.608	.2278	.0897	↓	↓
T-1	1	.2984	.1175	↓	↓	.2222	.0875	↓	↓
T-2	↓	.2921	.1150	↓	↓	.2159	.0850	↓	↓
T-3	↓	.2794	.1100	↓	↓	.2032	.0800	↓	↓
T-4	↓	.2667	.1050	↓	↓	.1905	.0750	↓	↓
T-5	5	.2540	.1000	↓	↓	.1778	.0700	↓	↓
T-6	1	.2413	.0950	1.5417	.607	.1651	.0650	↓	↓
T-7	1	.2286	.0900	1.5417	.607	.1524	.0600	↓	↓
T-8	4	.2159	.0850	1.5417	.607	.1397	.0550	↓	↓

^aGap to period ratio is nominally 0.3 but is subject to change in cold test to obtain the required match.

TABLE II. - QUALIFICATION VIBRATION
 REQUIREMENTS (VALUES ARE 1.5
 TIMES THE FLIGHT LEVELS)



(a) Sine sweep, two octaves per minute

Frequency, Hz	Vibrations level, g		
	Coordinate		
	X	Y	Z
5 - 14	Up to 5.0	----	----
14 - 100	5.0	----	----
5 - 16	---	Up to 6.0	----
16 - 40	---	6.0	----
40 - 100	---	10.0	----
5 - 25	---	----	Up to 15.0
25 - 70	---	----	15.0
70 - 120	---	----	4.0
120 - 250	---	----	2.3
100 - 250	2.3	2.3	----
250 - 400	4.5	4.5	4.5
400 - 2000	5.0	5.0	5.0

(b) Random duration, 90 seconds
 each axis

Frequency, Hz	Power spectral density, g^2/Hz	Vibration, g rms
20 - 300	+3 dB/octave	10.4
300 - 1000	$0.07 g^2/Hz$	10.4
1000 - 2000	-3 dB/octave	10.4

TABLE III. - QUALIFICATION AND ACCEPTANCE THERMAL REQUIREMENTS

	Condition	Temperature						VCHPS dissipa- tion, W		
		°C		°F		°C			°F	
		OST baseplate		PPS trans- former baseplate		VCHPS radiator				
Worst-case flight pre- dictions	Operating: Hot	48	118	56	133	60	140	163		
	Cold	0	32	0	32	----	----			
	Nonoperating (cold)	-8	18	-7	19	-140	-220		---	
Component acceptance	Hot	53	127	60	140	60	140	196		
	Cold	-5	23	-5	23	-140	-220			
	Minimum turn on	-5	23	-15	5	----	----			
Component qualification	Hot	58	136	65	149	65	149	216		
	Cold	-10	14	-10	14	-155	-247			
	Minimum turn on	-10	14	-20	-4	----	----			
System qualification on protoflight spacecraft	Hot	48	118	56	133	----	----	---		
	Cold	-5	23	-5	23	----	----			
	Minimum turn on	-5	23	-5	23	----	----			

TABLE IV. - ESTIMATED THERMAL DISSIPATIONS FOR
CTS OST 2022-R1

[After focus trimming at elevated temperature.]

Radiofre- quency power, W	Operating fre- quency, GHz	Temperature, °C		Heat rejection rate, W		
		Base- plate	Collector (MDC1) ^{a, b}	Base- plate	Output coupler	Collector ^b
^c 0	N.A.	45	158	25	0	132
93	^d 12.080	↓	172	67	7	132
^e 198	12.080	↓	122	166	9	108
^f 145	12.080	↓	138	177	7	126
^e 157	^g 12.123	↓	140	137	7	111
216	^h 12.038	↓	135	152	9	114

^aLocation of this instrument is shown in fig. 1. Does not represent either average or maximum MDC cover temperature

^bThese values do not include effects of solar input.

^cd.c. Beam.

^dCenter band.

^eSaturation.

^f3.5-dB overdrive.

^gUpper band edge.

^hLower band edge.

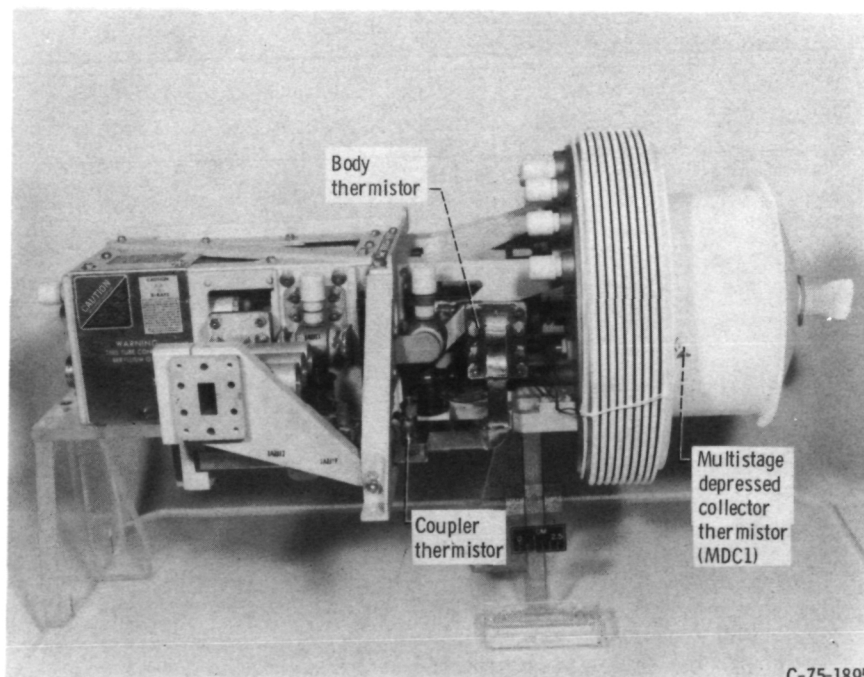
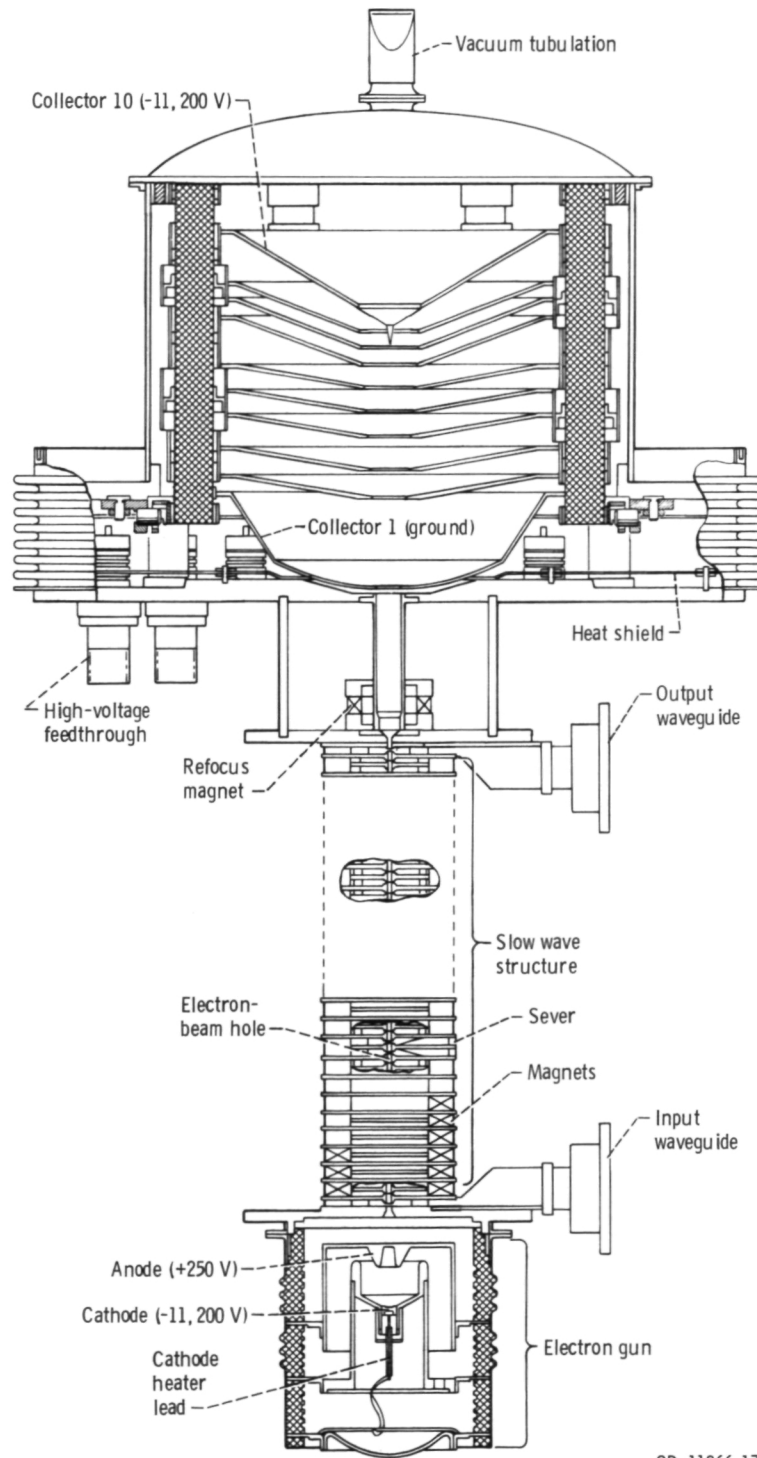


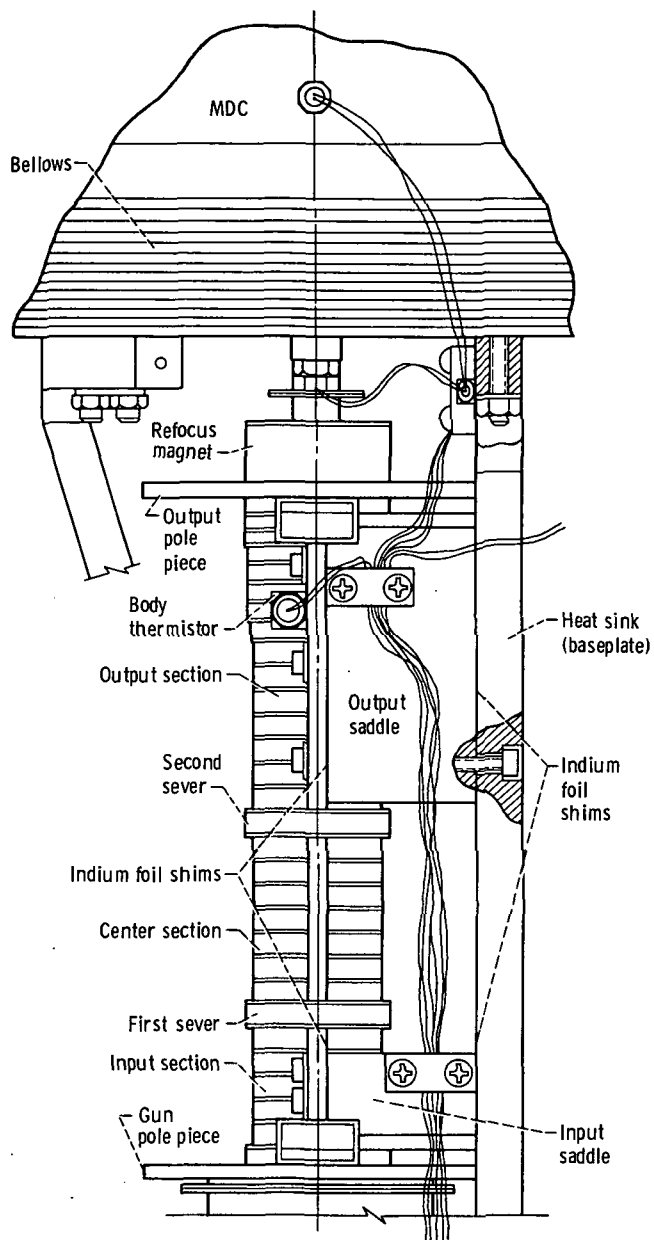
Figure 1. - Output stage tube 2030.



CD-11866-17

(a) Tube with collector.

Figure 2. - Coupled cavity traveling wave tube with multistage depressed collector.



(b) Detail of tube body.

Figure 2. - Concluded.

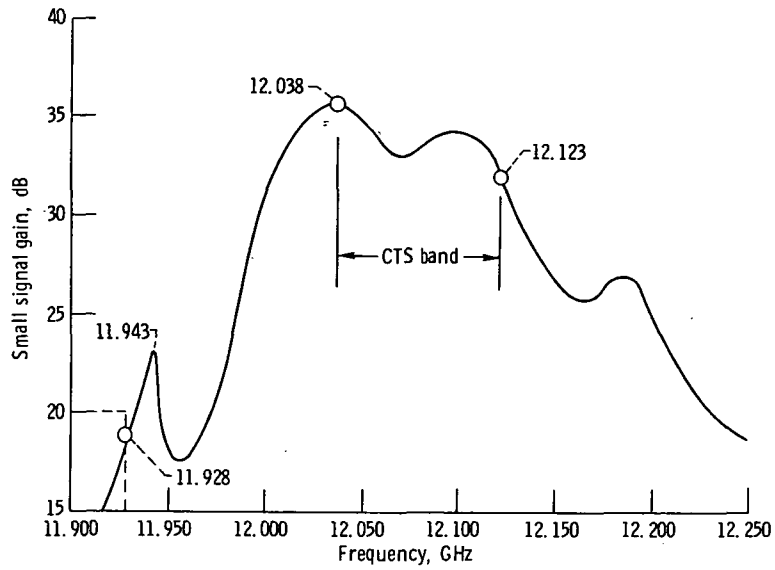


Figure 3. - Small signal gain as function of frequency for OST2022R-1.

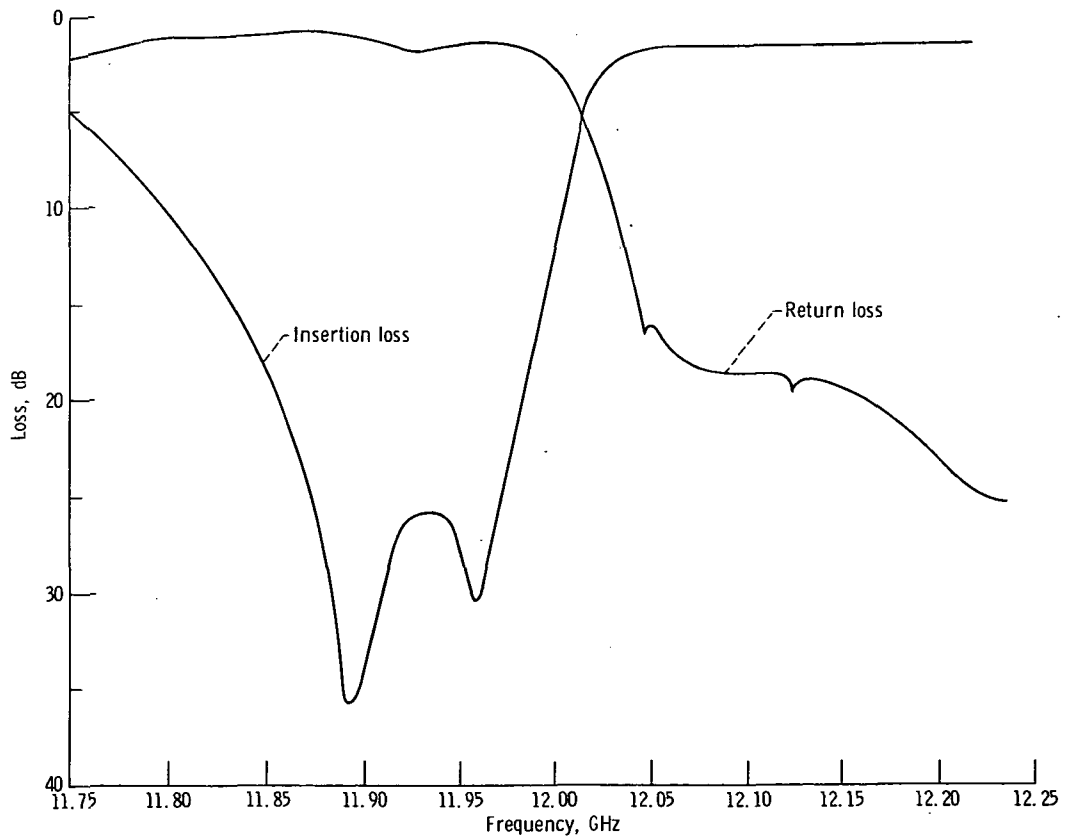


Figure 4. - Notch filter characteristics.

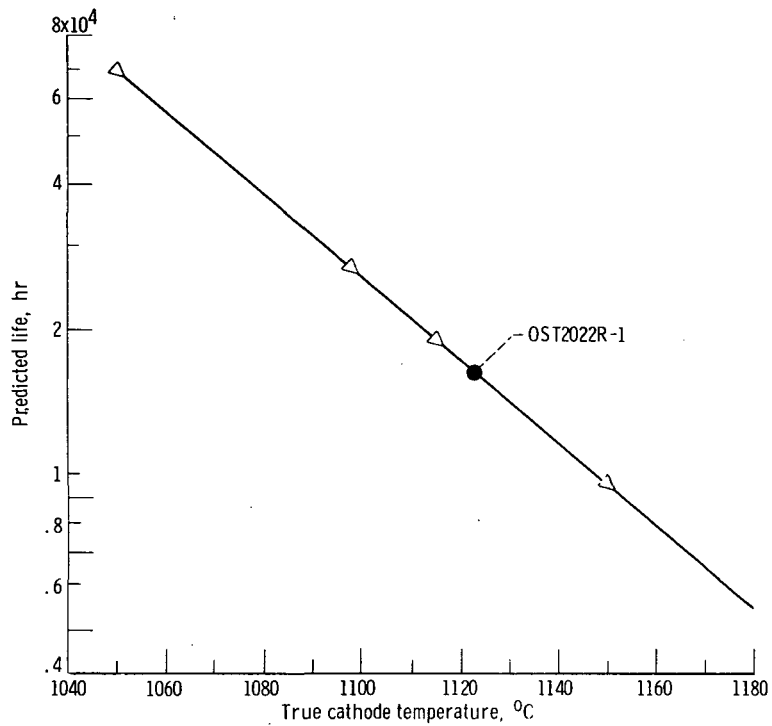


Figure 5. - Predicted cathode life as a function of true cathode temperature.

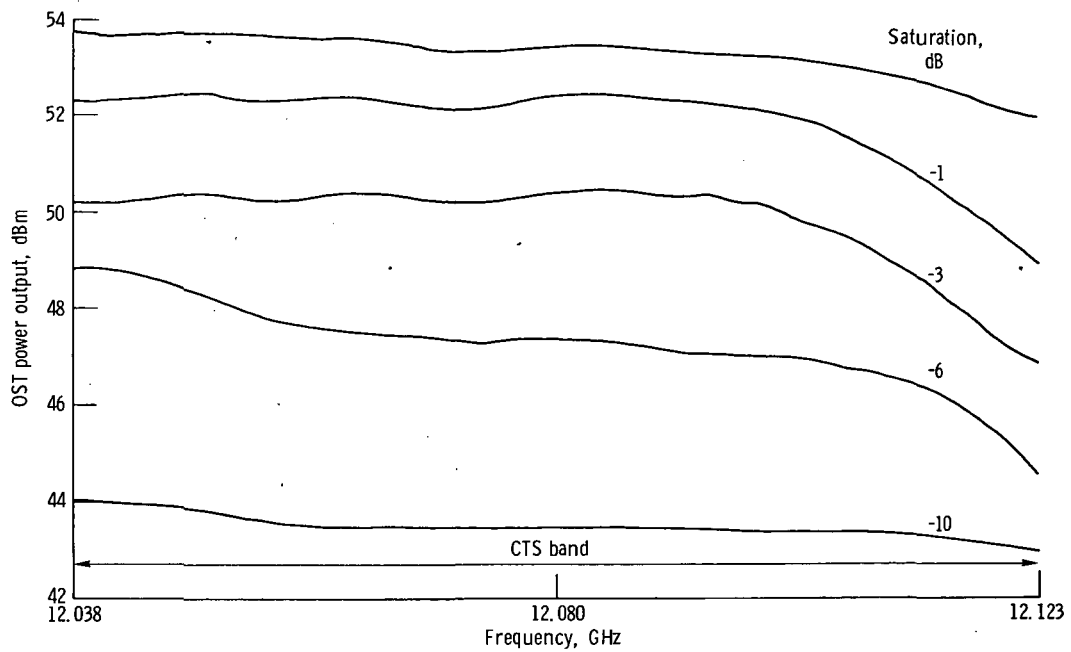


Figure 6. - OST output power as function of frequency.

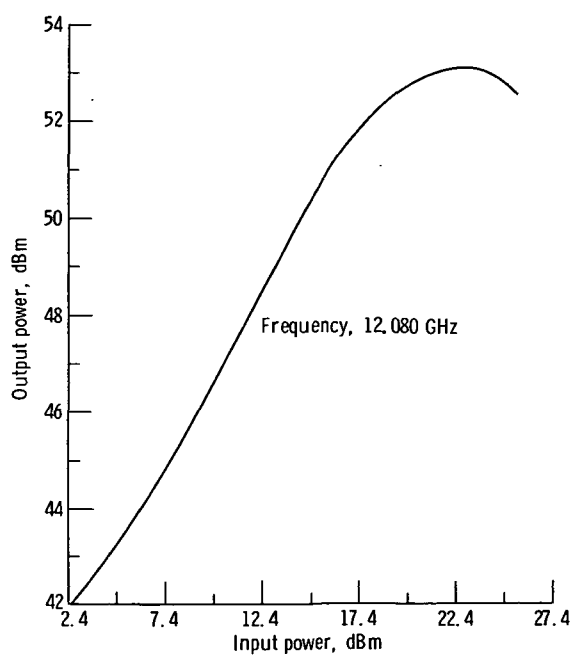


Figure 7. - OST power transfer curve.

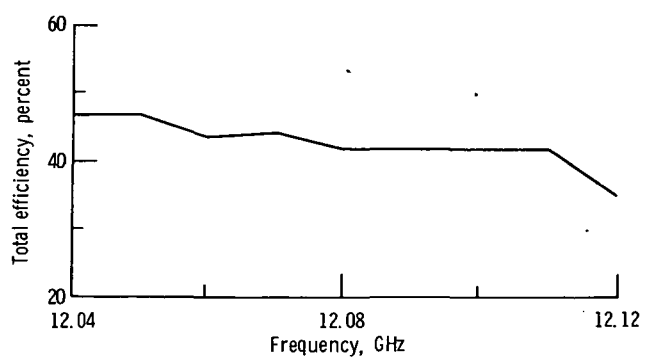


Figure 8. - OST efficiency as function of frequency.



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